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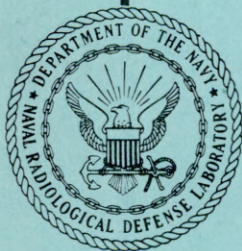
INVESTIGATION AND CORRELATION OF SOME PHYSICAL  
PARAMETERS OF FALLOUT MATERIAL

Research and Development Technical Report USNRDL-TR-152  
NS 081-001

28 March 1957

by

W. Williamson, Jr.



**U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY**

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INVESTIGATION AND CORRELATION OF SOME PHYSICAL  
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Physics and Mathematics

Technical Objective  
AW-7

Radiological Capabilities Branch  
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## ABSTRACT

An attempt has been made to correlate some of the fundamental physical parameters of fallout material. Parameters discussed are color and shape, activity, size, weight, and density. What little correlation that was possible among the accumulated data is presented together with the residual error.

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## SUMMARY

### The Problem

The problem was to investigate possible correlation between activity, color and shape, size, weight, and density of primary fallout particles.

### Findings

The investigation revealed a significant difference in density and activity in different types of fallout.

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## ADMINISTRATIVE INFORMATION

This work was done under Bureau of Ships Project No. NS 081-001, Subtask 1, Technical Objective AW-7, as described in U. S. Naval Radiological Defense Laboratory Annual Progress Report (DD Form 613) to the Bureau of Ships, July 1956.

The fallout studies were made at Operation REDWING, Project 2.6.3, as described in DD Form 613, NS 088-001, Subtask 4B, Encl (1) to CO USNRDL Secr ltr 3-905-335 Ser 0014173 of 16 March 1956.

The work also is part of the technical program for the Department of the Army established between Department of the Army, Office, Chief of Research and Development, and Bureau of Ships (Joint Agreement, 23 November 1955).

## ACKNOWLEDGMENTS

Appreciation is expressed to D. Pupione and B. Sine for aid in measuring the parameters, J. Mackin for permission to publish Fig. 2 and M. Sandomire for aid in statistical computations.

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## 1. INTRODUCTION

Operation REDWING provided NRDL with numerous field samples which were shipped to the Laboratory from the test site. Two of the shots, Zuni and Tewa, provided particles adequate for the measurement of physical parameters. The samples which were analyzed were designated as whim samples. The whim samples from both events were collected in the same manner, from the decks of a barge and a ship. The samples, which consisted of a large number of small particles, were scraped up, put into containers and sent back to the Laboratory for analysis or storage. There was one whim sample from Zuni which came from a barge, YFNB 29 and two whim samples from Tewa, one from the YFNB 29 and the other from a ship, YAG 39.<sup>(1)</sup>

The particles were analyzed to see what, if any, correlation existed between activity and a physical parameter. Activity of a particle refers to the net counts per minute, as detected under four-pi geometry by a thallium activated sodium iodide crystal.

## 2. PARAMETERS INVESTIGATED

The whim samples were scooped off the deck of a vessel which had been strategically located in the fallout area. It is assumed that the samples were chosen without discriminating against any particular size, color, weight, or shape. When the samples reached the Laboratory a small portion of the total sample was selected for analysis. In general, the particles selected for these analyses were randomly chosen, but some of their physical characteristics had been disturbed in handling the sample itself.\* Some of the particles were extremely fragile and were broken before, during, and after their selection.

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\* Zuni particles were sieved.

# U N C L A S S I F I E D

The physical parameters observed were color and shape, size, weight, and density. Each of these parameters merits further discussion about the method of measurement and the reproducibility and validity of the results.

## 2.1 Color and Shape

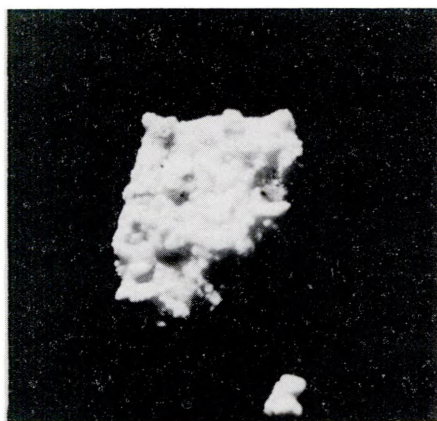
The color and shape of each particle chosen from the selected portion of the original whim sample were observed under a stereoscopic microscope. A field of view was chosen with an adequate number of single particles and then stripped of all particles. The particles were classified according to their apparent color under the microscope. The most prominent colors observed were yellowish-orange and white. The particles were also classified according to their shape (Fig. 1). The two most frequent shapes were irregular (Fig. 1a) and approximately spherical (Fig. 1b). Figure 1c shows an interesting feature common to most of the spheres observed; they were hollow.

It is interesting to note from the data given in Appendix A that among the colors seen were brown, brilliant yellow and sometimes even a greenish tinge. The frequency of these odd colored particles can sometimes be explained by the method of collecting the sample.

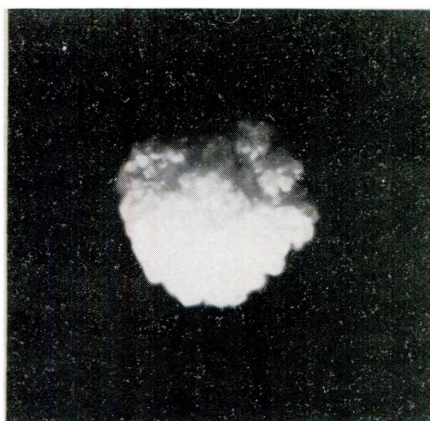
The number of gray porous particles found is of interest. It is possible that they represent particles formed in a different region of the cloud than are the spherical and irregular type. This would require further investigation and analysis of these particular types of particles.

## 2.2 Size

The parameter chosen to measure the size of a particle was the maximum projected diameter seen under a microscope. This method yielded reproducible measurements of size. The size of all Tewa particles selected was recorded.



a



b



c

Fig. 1 Examples of Sizes and Shapes of Fallout Particles Analyzed:  
(a) Irregular particle,  
(b) Spherical particle,  
(c) Spherical with hollow center.

# U N C L A S S I F I E D

## 2.3 Activity

All of the particles from both events were counted in a crystal well counter. Since the particles were counted over a period of many days, the counts had to be corrected to a common time in order that activities of the particles could be compared.

A general decay curve for each location and event of interest was plotted. The curve used for Zuni was the doghouse counter\*decay of YFNB 29-H-79, that for Tewa the doghouse decay of YFNB 29-H-79 and the well counter decay curve of YAG 39-C-21.<sup>(1)</sup> It was necessary to make two assumptions: (1) that the doghouse and well counter decay curves have the same slope, and (2) that all particles decay with slopes similar to the general decay curves from the same location as the particle. Both of these assumptions are open to justifiable criticisms. A plot showing the decay of two particles picked off the same collector is shown in Fig. 2. This plot illustrates the weakness of the second assumption. When considering the difference in decay slope for individual particles, as well as the difference in slope which characterizes a counter's efficiency, then the validity of correction to a common time is questionable. Although the activity (c/m) of a particle is reproducible, the ratio of the activities of two particles counted on D+40 and corrected to D+30 is not necessarily a constant and the error introduced is not a constant one.

## 2.4 Weight

A number of particles from Tewa whim samples were weighed with an Ainsworth microbalance. The principal error introduced in weighing was due to crumbling of particles during handling.

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\* A large shielded scintillation counter, colloquially termed "doghouse" because of its size and shape.

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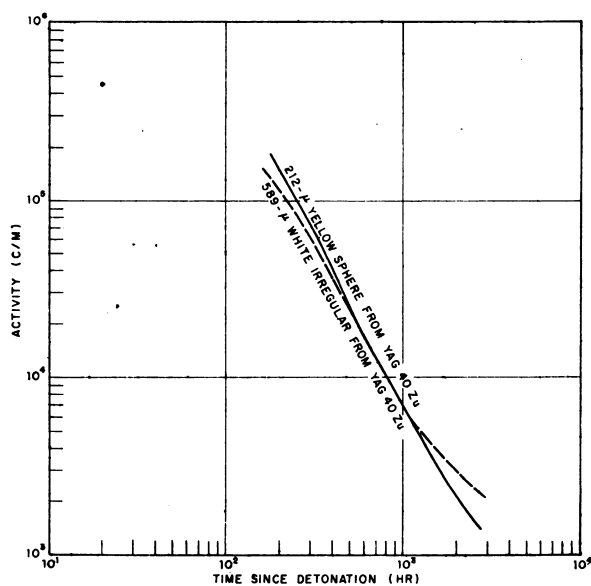


Fig. 2 Decay curves of two particles from the same collector.

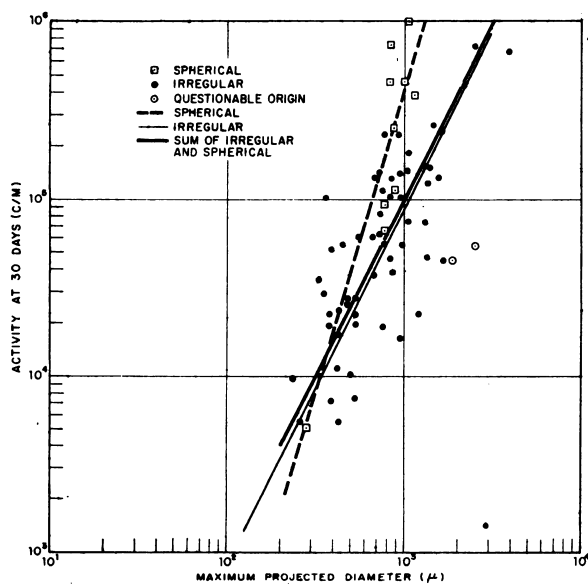


Fig. 3 Activity as a function of maximum projected particle diameter.



## 2.5 Density

The density of a particle was determined by letting it come to an equilibrium point in a density gradient tube. The gradient was made with mixtures of bromoform and bromobenzene with density ranges from 2.0 to 2.8 g/cu cm. The ratio of bromoform to bromobenzene to yield a given density mixture was first calculated. Then the density of the mixture was checked with a refractometer.

The errors introduced in determining the density of small porous particles are numerous and a few are quite critical. The most significant error is introduced by the amount of air trapped in any cavities the particle possesses. This error can be minimized by giving the gradient tube a sharp rap on the side after a particle has entered. This rap releases most of the trapped air and allows a particle to fall to an equilibrium position. Some other errors are; (a) the amount of the particle dissolved by the mixture, (b) the slowing down of a particle as it crosses a boundary layer which frequently introduces faulty recording of density, and (c) convection currents in the tube.

## 3. CORRELATION OF PARAMETERS

Having in mind the above errors which are introduced when physical measurements of small particles are made will aid in understanding the difficulty of attempting to correlate the parameters.

### 3.1 Size vs Activity

The size-activity plot for the combined particles from the test vessels, YAG 39 and YFNB 29, Event Tewa, is shown in Fig. 3. It indicates that there is a trend

U N C L A S S I F I E D

of increasing activity with particle size. Some of the prominent scattering can be explained by highly irregular particles. By examining some of the particles on the periphery of the plot a better insight into the scattering can be gained. Four of these particles and their characteristics from Appendix A are shown in Fig. 4. The two particles circled in Fig 3 are shown in Fig. 4b and c, thus some of the scattering can be attributed to background particles that had become contaminated.

The correlation between size and activity for all sixty nine Tewa particles was found by least squares, assuming a logarithmic relationship, to be

$$A_{(D+30)} = 9 \times 10^{-2} D^{2.01} \quad (1)$$

with a residual error\* of 206%

where

$A_{(D+30)}$  = activity (c/m) at thirty days since detonation.

D = maximum projected diameter (microns).

It is evident that the activity range for any given diameter is so large that no definite function can adequately describe the correlation.

The spherical particles in Fig. 3 are identified by squares. The relation found using the same assumptions as above is

$$A_{(D+30)} = 2.76 \times 10^{-5} D^{3.37} \quad (2)$$

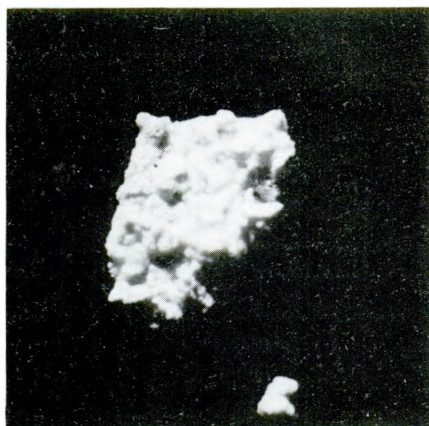
with a residual error of 430% and a total of only nine particles.

The relationship for all sixty irregular particles is

$$A_{(D+30)} = 1.36 \times 10^{-1} D^{1.92} \quad (3)$$

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\* Residual error is the error which cannot be attributed to the linear regression.



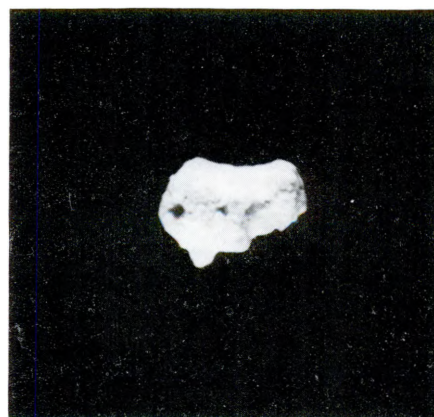
a



b



c



d

- Fig. 4 Assorted Fallout Particles:
- (a) Particle 158, white irregular,  $2508 \mu$   $7.2 \times 10^5 \text{c/m}$  at D+30,
  - (b) Particle 166, brown irregular,  $2508 \mu$ ,  $5.4 \times 10^4 \text{c/m}$  at D+30, presumably not a fallout particle,
  - (c) Particle 177, white irregular (grooves like a shell),  $1881 \mu$ ,  $4.4 \times 10^4 \text{c/m}$  at D+30, believed to be a piece of shell on the barge before the shot,
  - (d) Particle 195, white irregular  $2112 \mu$ ,  $4.4 \times 10^5 \text{c/m}$  at D+30.

# U N C L A S S I F I E D

and the residual error, 191%.

From the above results, it would seem any estimates for activity of a number of spherical particles would be expected from Eq. 1 to be low while the same measured D for a number of irregular particles would yield a high activity value.\* This indicates one must not speak of activity vs size but rather activity vs size vs particle type. The resulting dispersion and the above fact seems to indicate that a new size parameter which describes the irregularity of a particle may merit further investigation.

## 3.2 Weight vs Activity

Figure 5 shows a weight-activity plot. A linear relationship on log log paper was hypothesized and a curve fitted using the method of least squares. The relationship is

$$A = 3.2 \times 10^3 W^{0.7} \quad (4)$$

and the residual error = 136%

where W = weight, ( $\mu$ g).

The dashed lines on Fig. 5 represents 95% confidence intervals. A relationship between activity, weight, and maximum projected diameter was found by treating each as variables and using least squares.

$$A = 178 W^{0.35} D^{0.63} \quad (5)$$

It has been hypothesized<sup>(2)</sup> that fallout particles, which in the Eniwetok Proving Ground are chiefly calcium compounds, are influenced by the following reaction:

\* As seen on Fig. 3., this is only true for particles greater than 320 microns.

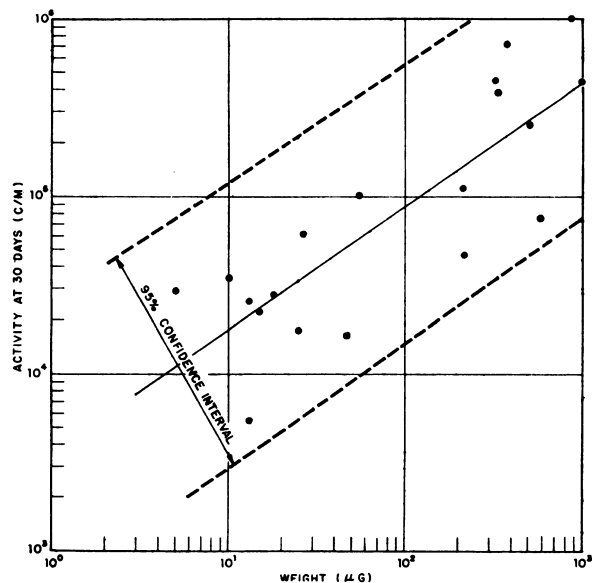


Fig. 5 Activity as a function of the particle weight.

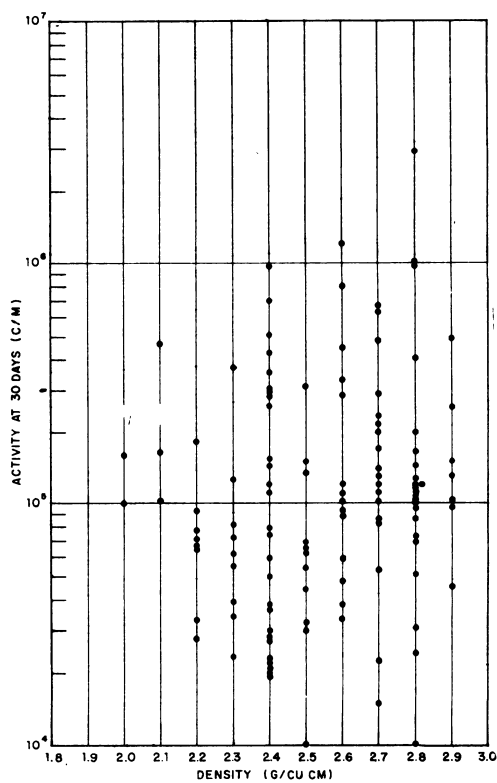


Fig. 6 Activity as a function of the particle density.

$\text{CaCO}_3 \rightarrow \text{CO}_2 + \text{CaO} \xrightarrow{\text{H}_2\text{O}} \text{Ca(OH)}_2 + \text{CO}_2 \xrightarrow{\sim 10\%} \text{CaCO}_3 + \text{H}_2\text{O}$ , which has an adverse effect on any weight or density parameter measured. The increase in weight as a function of time would depend upon the quantity of  $\text{CaCO}_3$  present, porosity, surface area, and the atmosphere surrounding the particle. It is evident that as a function of time the activity of each particle would decrease while its mass increases. The change in mass as a function of time is only significant at early times, such as 2 to 8 hr after detonation.

The preceding equations can be considered only approximate functional relationships with sizeable residual errors. It appears, however, that the activity is functionally related to the weight and projected diameter of a particle, this function still not being adequately described.

### 3.3 Density vs Activity

A density-activity plot is shown in Fig. 6. These particles were selected from the Zuni samples. The plot shows no apparent correlation between activity and density.

Inspection of Fig. 6 shows a clustering of particles at  $\rho = 2.3$  and  $\rho = 2.7$ . A plot of the percentage of particles falling in a given density range vs density is shown in Fig. 7. The heavy line, percentage of total particles falling in a given density, most clearly demonstrates the clustering. The prominent peaks are at  $\rho = 2.3$  and  $\rho = 2.7$ . To further examine these peaks a plot was made showing the percentage of yellow and white spheres with a given density. The maximum of the white spheres fall at  $\rho = 2.3$ , and the maximum of the yellow at  $\rho = 2.7$ . The density distribution is recorded in Table 1. It seems valid to say that the yellow spheres are more dense than the white.

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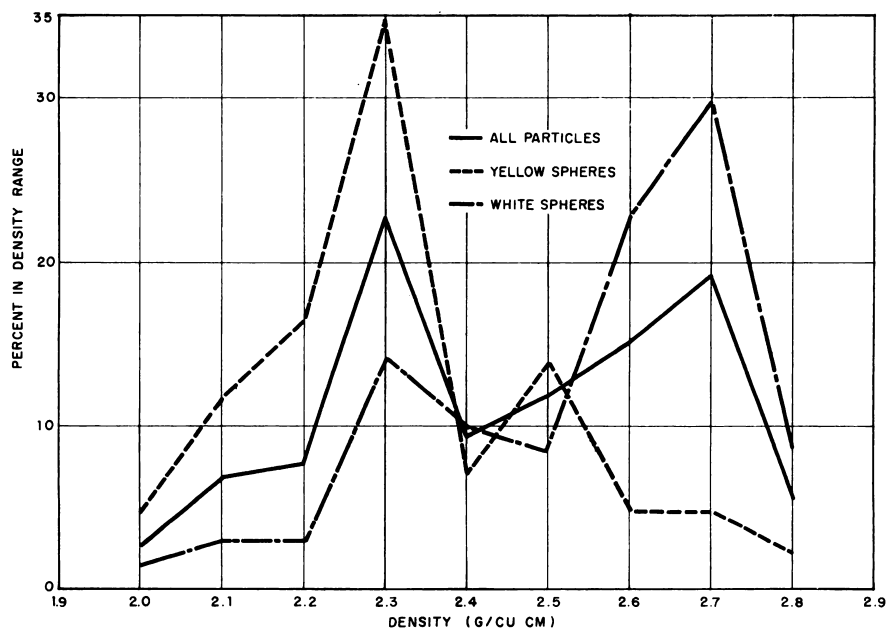


Fig. 7 Density distribution of the particles analyzed.

Table 1 Density Distribution

Total number of particles (N) - 120

Total number of yellow spheres - 71

Total number of white spheres - 43

Mean density of all spheres ( $\bar{\rho} = \frac{\sum f_i \rho_i}{N}$ ) = 2.46

Mean density of yellow spheres - 2.53 gm/cm<sup>3</sup>

Mean density of white spheres - 2.33 gm/cm<sup>3</sup>

Density (g/cm <sup>3</sup> )	Percentage of Total Particles	Percentage of Yellow Spheres	Percentage of White Spheres
2.0	2.5	1.4	4.7
2.1	6.7	2.8	11.6
2.2	7.5	2.8	16.3
2.3	22.5	14.0	35.0
2.4	9.2	9.9	7.0
2.5	11.7	8.5	13.9
2.6	15.0	22.6	4.7
2.7	19.2	29.6	4.7
2.8	5.8	8.5	2.3

The activity range of the particles is shown in Table 2.



Table 2 Activity Range

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		Activity at D+30 (c/m)			
		$10^3-10^4$	$10^4-10^5$	$10^5-10^6$	$10^6-10^7$
Percentage of spheres in activity range	yellow	-	36	60	4
	white	5	55	40	-

---

Thus it would appear that the yellow spheres are more active than the white ones. Combining these results could mean that the yellow spheres are produced in a different region of the cloud than the white.

#### 4. SUMMARY

The results of this investigation may be summarized as follows; (a)  $A = K_1 D^n$  and  $A = K_2 W^n$  each of which must be derived and applied to its own species, after this is done there is still a sizeable residual error, (b) the yellow spheres are more dense than the white ones, and (c) the order of increasing activity seems to be white irregular, white spheres, and yellow spheres.

The hope of finding better defined functions between particle activity and physical parameters awaits improvements in defining these parameters and the collection of more data.

Approved by:

*E. R. Tompkins*  
E.R. TOMPKINS

For the Scientific Director

U N C L A S S I F I E D

#### References

1. T. Triffet and others, "Characterization of Fallout", Operation REDWING, USNRDL-IIR-1317. (CLASSIFIED).
2. C.E. Adams, "The Nature of Individual Radioactive Particles, V. Fallout Particles from Shots Zuni and Tewa", Operation REDWING, USNRDL-TR-133, 1 Feb. 1957 (CLASSIFIED).

U N C L A S S I F I E D



Appendix A

SINGLE PARTICLE ANALYSIS

The results of the analyses of 196 particles are listed below:

<u>Specification of Particle</u>			<u>Parameters</u>			
No.	Event	Location	Shape and Color	Size ( $\mu$ )	Activity at D + 30 (c/m)	Mass ( $\mu$ g) Density ( $\text{g/cm}^3$ )
	Zuni	Whim Sample YFNB 29				
1			White Sphere		$1.51 \times 10^4$	
2			White Irregular		$3.05 \times 10^4$	2.4
3			White Irregular		$2.23 \times 10^4$	2.3
4			Yellow Sphere		$2.30 \times 10^5$	2.6
5			Yellow Sphere		$6.30 \times 10^5$	2.6
6			Yellow Sphere		$3.25 \times 10^5$	2.5
7			White Sphere		$1.40 \times 10^5$	2.6
8			Yellow Sphere		$9.6 \times 10^5$	2.3
9			Yellow Sphere		$3.7 \times 10^5$	2.2
10			Yellow Sphere		$7.9 \times 10^5$	2.5
11			Yellow Sphere		$7.0 \times 10^5$	2.3
12			Yellow Sphere		$1.1 \times 10^5$	2.6
13			Yellow Sphere		$2.05 \times 10^5$	2.6
14			White Sphere		$3.8 \times 10^4$	2.3

U N C L A S S I F I E D

SINGLE PARTICLE ANALYSIS

<u>Specification of Particle</u>			<u>Parameters</u>			
<u>No.</u>	<u>Event</u>	<u>Location</u>	<u>Shape and Color</u>	<u>Size (<math>\mu</math>)</u>	<u>Activity at D + 30 (c/m)</u>	<u>Mass (<math>\mu</math>g)</u> <u>Density (<math>\text{g/cm}^3</math>)</u>
	Zuni	Whim Sample YFNB 29				
15			Yellow Sphere		$3.5 \times 10^5$	2.3
16			1/2 White Sphere		$2.9 \times 10^5$	2.3
17			White Sphere		$1.09 \times 10^5$	2.0
18			White Sphere		$1.25 \times 10^5$	2.2
19			Yellow Sphere		$2.75 \times 10^4$	2.1
20			Yellow Sphere		$2.9 \times 10^5$	2.6
21			Yellow Irregular		$5.2 \times 10^3$	2.1
22			White Sphere		$3.3 \times 10^4$	2.1
23			Green Irregular		$3.7 \times 10^4$	2.3
24			Yellow Sphere		$4.9 \times 10^5$	2.7
25			White Sphere		$7.8 \times 10^4$	2.3
26			White Sphere		$4.0 \times 10^5$	2.7
27			Yellow Sphere		$2.08 \times 10^4$	2.3
28			Yellow Sphere		$4.6 \times 10^5$	2.0

U N C L A S S I F I E D

SINGLE PARTICLE ANALYSIS

Specification of Particle			Parameters			
No.	Event	Location	Shape and Color	Size ( $\mu$ )	Activity at D + 30 (c/m)	Mass ( $\mu$ g) Density ( $\text{g/cm}^3$ )
	Zuni	Whim Sample YFNB 29				
29			Yellow Irregular		$1.21 \times 10^6$	2.5
30			White Sphere		$7.4 \times 10^3$	2.3
31			Yellow Sphere		$2.25 \times 10^4$	2.6
32			Yellow Sphere		$4.4 \times 10^5$	2.5
33			White Sphere		$3.4 \times 10^4$	2.2
34			Yellow Sphere		$1.5 \times 10^5$	2.7
35			Yellow Sphere		$6.8 \times 10^4$	2.4
36			White Sphere		$3.1 \times 10^5$	2.4
37			1/2 White Sphere		$1.5 \times 10^5$	2.3
38			3/4 Yellow Sphere		$6.25 \times 10^4$	2.1
39			White Sphere		$7.7 \times 10^4$	2.1
40			White Sphere		$2.8 \times 10^5$	2.3
41			Yellow Sphere		$2.5 \times 10^5$	> 2.7
42			White Sphere		$2.8 \times 10^5$	2.5

SINGLE PARTICLE ANALYSIS

<u>Specification of Particle</u>			<u>Parameters</u>				
No.	Event	Location	Shape and Color	Size ( $\mu$ )	Activity at D + 30 (c/m)	Mass ( $\mu$ g)	Density (g/cm <sup>3</sup> )
	Zuni	Whim Sample YFNB 29					
43			White Sphere		$2.7 \times 10^4$		2.3
44			Yellow Sphere		$6.5 \times 10^4$		2.4
45			1/2 White Sphere		$5.9 \times 10^4$		2.3
46			White Sphere		$9.2 \times 10^4$		2.5
47			White Sphere		$7.0 \times 10^4$		2.1
48			Yellow Sphere		$2.9 \times 10^6$		2.7
49			Yellow Sphere		$4.4 \times 10^4$		2.41
50			White Sphere		$5.0 \times 10^5$		2.3
51			3/4 White Sphere		$3.5 \times 10^5$		2.3
52			White Sphere		$8.7 \times 10^4$		2.5
53			White Irregular		$2.45 \times 10^3$		2.6
54			White Sphere		$4.2 \times 10^5$		2.3
55			Yellow Sphere		$6.7 \times 10^5$		2.6
56			Green Irregular		$9.2 \times 10^4$		2.1

U N C L A S S I F I E D

SINGLE PARTICLE ANALYSIS

Specification of Particle			Parameters				
No.	Event	Location	Shape and Color	Size ( $\mu$ )	Activity at D + 30 (c/m)	Mass ( $\mu$ g)	Density (g/cm <sup>3</sup> )
	Zuni	Whim Sample YFNB 29					
57			White Sphere		$7.4 \times 10^4$		2.3
58			White Sphere		$1.58 \times 10^5$		2.0
59			Yellow Sphere		$2.6 \times 10^5$		2.3
60			Yellow Sphere		$4.8 \times 10^5$		2.6
61			Green Sphere		$3.8 \times 10^4$		2.5
62			Yellow Sphere		$1.25 \times 10^5$		2.7
63			White Sphere		$6.6 \times 10^4$		2.1
64			Yellow Sphere		$5.9 \times 10^4$		2.5
65			Yellow Sphere		$1.2 \times 10^5$		2.5
66			Yellow Sphere		$1.12 \times 10^5$		2.3
67			White Sphere		$5.4 \times 10^4$		2.2
68			Yellow Sphere		$1.2 \times 10^5$		2.7
69			Yellow Sphere		$5.2 \times 10^4$		2.4
70			Yellow Sphere		$3 \times 10^4$		2.7

U N C L A S S I F I E D



## SINGLE PARTICLE ANALYSIS

<u>Specification of Particle</u>		<u>Parameters</u>				
<u>No.</u>	<u>Event</u>	<u>Location</u>	<u>Shape and Color</u>	<u>Size (<math>\mu</math>)</u>	<u>Activity at D + 30 (c/m)</u>	<u>Mass (<math>\mu</math>g)</u> <u>Density (g/cm<sup>3</sup>)</u>
	Zuni	Whim Sample YFNB 29				
71			Yellow Sphere		$1.7 \times 10^5$	2.6
72			White Sphere		$6.1 \times 10^4$	2.2
73			Yellow Sphere		$1.53 \times 10^5$	2.4
74			White Sphere		$2.85 \times 10^4$	2.3
75			White Sphere		$1.0 \times 10^5$	2.5
76			Yellow Sphere		$1.18 \times 10^5$	2.6
77			White Sphere		$7.2 \times 10^4$	2.2
78			Yellow Sphere		$1.42 \times 10^5$	2.3
79			White Sphere		$2.3 \times 10^4$	2.2
80			White Sphere		$2.1 \times 10^4$	2.3
81			Yellow Sphere		$6.9 \times 10^4$	2.7
82			Yellow Sphere		$1.03 \times 10^4$	2.7
83			Yellow Sphere		$2.05 \times 10^5$	2.7
84			Yellow Sphere		$1.28 \times 10^5$	2.4

U N C L A S S I F I E D

SINGLE PARTICLE ANALYSIS

Specification of Particle			Parameters				
No.	Event	Location	Shape and Color	Size ( $\mu$ )	Activity at D + 30 (c/m)	Mass ( $\mu$ g)	Density (g/cm <sup>3</sup> )
	Zuni	Whim Sample YFNB 29					
85			Yellow Sphere		$9.6 \times 10^4$		2.8
86			Yellow Sphere		$1.02 \times 10^5$		2.7
87			White Sphere		$9.8 \times 10^3$		2.4
88			Yellow Sphere		$1.2 \times 10^5$		2.3
89			Yellow Sphere		$8.0 \times 10^4$		2.2
90			1/2 Yellow Sphere		$5.3 \times 10^4$		2.6
91			Yellow Sphere		$2.9 \times 10^4$		2.3
92			Yellow Sphere		$2.35 \times 10^5$		2.6
93			Yellow Sphere		$1.05 \times 10^6$		2.7
94			Yellow Sphere		$1.3 \times 10^5$		2.6
95			Yellow Sphere		$9.9 \times 10^5$		2.7
96			White Irregular		$2.4 \times 10^4$		2.7
97			Yellow Sphere		$8.6 \times 10^4$		2.6
98			Yellow Sphere		$1.3 \times 10^5$		2.8

U N C L A S S I F I E D

U N C L A S S I F I E D

## SINGLE PARTICLE ANALYSIS

Specification of Particle			Parameters				
No.	Event	Location	Shape and Color	Size ( $\mu$ )	Activity at D + 30 (c/m)	Mass ( $\mu$ g)	Density (g/cm <sup>3</sup> )
	Zuni	Whim Sample YFNB 29					
99			White Sphere		$3.2 \times 10^4$		2.4
100			White Sphere		$1.43 \times 10^5$		2.7
101			Yellow Sphere		$5.1 \times 10^4$		2.7
102			Yellow Sphere		$1.09 \times 10^5$		2.6
103			White Sphere		$5.0 \times 10^3$		2.4
104			Yellow Sphere		$6.9 \times 10^4$		2.7
105			Yellow Sphere		$1.63 \times 10^5$		2.7
106			White Sphere		$1.08 \times 10^5$		2.5
107			Yellow Sphere		$4.8 \times 10^4$		2.5
108			White Sphere		$3.3 \times 10^4$		2.5
109			White Sphere		$5.0 \times 10^4$		2.3
110			Yellow Sphere		$1.1 \times 10^5$		2.7
111			Yellow Sphere		$1.05 \times 10^5$		2.7
112			Yellow Sphere		$8.6 \times 10^4$		2.7

U N C L A S S I F I E D

SINGLE PARTICLE ANALYSIS

<u>Specification of Particle</u>			<u>Parameters</u>				
No.	Event	Location	Shape and Color	Size ( $\mu$ )	Activity at D + 30 (c/m)	Mass ( $\mu$ g)	Density (g/cm <sup>3</sup> )
	Zuni	Whim Sample YFNB 29					
113			White Sphere		$4.5 \times 10^4$		2.8
114			Yellow Sphere		$1.2 \times 10^5$		2.7
115			Yellow Sphere		$8.5 \times 10^4$		2.6
116			Yellow Sphere		$6.5 \times 10^4$		2.4
117			White Sphere		$1.5 \times 10^4$		2.6
118			Yellow Sphere		$1.1 \times 10^5$		2.7
119			Yellow Sphere		$2.0 \times 10^4$		2.3
120			Yellow Sphere		$7.0 \times 10^4$		2.7
121			Yellow Sphere		$1.0 \times 10^5$		2.8
122			Yellow Sphere		$1.2 \times 10^5$		2.7
123			White Sphere		$3.9 \times 10^4$		2.2
124			White Irregular		$2.3 \times 10^4$		2.3
125			Yellow Sphere		$9.8 \times 10^4$		2.7
126			White Sphere		$1.8 \times 10^5$		2.1

SINGLE PARTICLE ANALYSIS

Specification of Particle			Parameters				
No.	Event	Location	Shape and •Color	Size ( $\mu$ )	Activity at D + 30 (c/m)	Mass ( $\mu$ g)	Density (g/cm <sup>3</sup> )
	Tewa	Whim Sample YAG-39					
127			White Sphere	281	$5.0 \times 10^3$		
128			White Irregular	841	$1.0 \times 10^5$	55	
129			White Irregular(a)	429	$1.7 \times 10^4$	25	
130			White Irregular(b)	858	$1.3 \times 10^5$		
131			White Irregular	495	$2.7 \times 10^4$	18	
132			White Irregular	330	$3.4 \times 10^4$	10	
133			White Irregular	380	$2.2 \times 10^4$	15	
134			White Irregular	479	$2.5 \times 10^4$	13	
135			White Irregular	330	$8.5 \times 10^3$		
136			White Irregular	264	$5.4 \times 10^3$		
137			White Irregular	957	$1.6 \times 10^4$	47	
138			White Irregular	363	$2.9 \times 10^4$	5	
139			White Irregular(c)	561	$6.0 \times 10^4$	27	
140			White Irregular	1386	$4.6 \times 10^4$	216	

SINGLE PARTICLE ANALYSIS

Specification of Particle			Parameters				
No.	Event	Location	Shape and Color	Size ( $\mu$ )	Activity at D + 30 (c/m)	Mass ( $\mu$ g)	Density (g/cm <sup>3</sup> )
	Tewa	Whim Sample YAG-39					
141			White Irregular	429	$5.4 \times 10^3$	13	
142			White Irregular	1056	$2.8 \times 10^5$		
143			White Irregular(d)	792	$5.4 \times 10^4$		
144			White Irregular	462	$5.2 \times 10^4$		
145			White Irregular	429	$1.1 \times 10^4$		
146			White Irregular	528	$2.7 \times 10^4$		
147			White Irregular	1221	$2.2 \times 10^4$		
148			White Irregular	957	$2.0 \times 10^5$		
149			No sample				
150			White Irregular	1386	$1.2 \times 10^5$		
151			White Irregular	528	$7.5 \times 10^3$		
152			White Irregular	495	$1.0 \times 10^4$		
153			White Irregular	363	$1.0 \times 10^5$		
154			White Irregular(e)	660	$6.0 \times 10^4$		

SINGLE PARTICLE ANALYSIS

<u>Specification of Particles</u>		<u>Parameters</u>				
No.	Event	Location	Shape and Color	Size ( $\mu$ )	Activity at D + 30 (c/m)	Mass ( $\mu$ g) Density ( $\text{g/cm}^3$ )
	Tewa	Whim Sample Yag-39				
155			White Irregular	396	$5.1 \times 10^4$	
156			White Irregular	693	$1.3 \times 10^5$	
157			White Irregular	396	$7.2 \times 10^3$	
158			White Irregular(f)	2508	$7.2 \times 10^5$	
159			White Irregular(f)	528	$1.9 \times 10^4$	
160			White Irregular(f)	396	$1.9 \times 10^4$	
161			White Irregular	231	$9.5 \times 10^3$	
162			White Irregular	429	$2.3 \times 10^4$	
	Tewa	Whim Sample YFNB 29				
163			Yellow Sphere(f)	821	$4.5 \times 10^5$	310
164			Yellow Sphere	1122	$3.8 \times 10^5$	321
165			Yellow Sphere	825	$7.2 \times 10^5$	397
166			Brown Irregular(g)	2508	$5.4 \times 10^4$	
167			White Sphere	891	$2.5 \times 10^5$	505

U N C L A S S I F I E D

SINGLE PARTICLE ANALYSIS

Specification of Particles			Parameters				
No.	Event	Location	Shape and Color	Size ( $\mu$ )	Activity at B + 30 (c/m)	Mass ( $\mu$ g)	Density ( $\text{g/cm}^3$ )
	Tewa	Whim Sample YFNB 29					
168			White Irregular	759	$1.1 \times 10^5$	220	
169			Yellow Sphere	1056	$1.0 \times 10^6$	866	
170			White Irregular	1320	$7.2 \times 10^4$	584	
171			White Irregular(h)	1881	$4.4 \times 10^4$		
172			White Irregular(i)	1683	$4.4 \times 10^5$		
173			Grey Irregular(j)	990	$5.4 \times 10^4$		
174			White Irregular	957	$1.4 \times 10^5$		
175			White Irregular	1320	$1.5 \times 10^5$		
176			White Irregular	924	$2.3 \times 10^5$		
177			White Irregular	1023	$1.4 \times 10^5$		
178			White Sphere	891	$1.1 \times 10^5$		
179			White Irregular	1056	$4.6 \times 10^5$		
180			White Irregular	1587	$1.3 \times 10^5$		
181			White Sphere	792	$9.2 \times 10^4$		

U N C L A S S I F I E D



SINGLE PARTICLE ANALYSIS

<u>Specification of Particle</u>			<u>Parameters</u>				
No.	Event	Location	Shape and Color	Size ( $\mu$ )	Activity at D + 30 (c/m)	Mass ( $\mu$ g)	Density (g/cm <sup>3</sup> )
	Tewa	Whim Sample YFNB 29					
182			White Irregular	759	$1.9 \times 10^4$		
183			Grey Irregular	693	$3.6 \times 10^4$		
184			White Irregular	825	$3.8 \times 10^4$		
185			White Irregular	1386	$1.5 \times 10^5$		
186			White Irregular	1452	$2.6 \times 10^5$		
187			White Irregular	726	$8.0 \times 10^4$		
188			White Irregular	528	$2.2 \times 10^4$		
189			White Irregular	726	$6.3 \times 10^4$		
190			White Irregular	1056	$7.4 \times 10^4$		
191			White Irregular	1617	$2.4 \times 10^5$		
192			White Sphere	792	$6.5 \times 10^4$		
193			White Irregular	726	$1.4 \times 10^5$		
194			1/2 White Sphere	759	$2.3 \times 10^5$		

## SINGLE PARTICLE ANALYSIS

<u>Specification of Particle</u>			<u>Parameters</u>				
<u>No.</u>	<u>Event</u>	<u>Location</u>	<u>Shape and Color</u>	<u>Size (<math>\mu</math>)</u>	<u>Activity at D + 30 (c/m)</u>	<u>Mass (<math>\mu</math>g)</u>	<u>Density (g/cm<sup>3</sup>)</u>
Tewa		Whim Sample YFNB 29					
195			White Irregular	2112	$4.4 \times 10^5$		
196			White Irregular	3960	$6.8 \times 10^5$		

- 
- (a) White irregular with two black dots.
  - (b) White irregular with one black dot.
  - (c) Conglomeration of smaller spheres.
  - (d) White irregular with dark yellow spot.
  - (e) Black discoloration on one end.
  - (f) Photographed.
  - (g) Yellow and silver discoloration.
  - (h) Had grooves like a clam shell.
  - (i) 1140.
  - (j) Very porous.



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INVESTIGATION AND CORRELATION OF SOME  
PHYSICAL PARAMETERS OF FALLOUT MATERIAL,  
by W. Williamson, Jr. 28 Mar. 1957. 36 p.  
illus. UNCLASSIFIED

An attempt has been made to correlate some of  
the fundamental physical parameters of fallout ma-  
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correlation that was possible among the accumulated  
data is presented together with the residual error.

1. Fallout
2. Radioactive substances
- I. Williamson, W., Jr.
- II. Operation REDWING
- III. NS 081-001

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- III. NS 081-001

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Appendix A

SINGLE PARTICLE ANALYSIS

The results of the analyses of 196 particles are listed below:

<u>Specification of Particle</u>			<u>Parameters</u>			
No.	Event	Location	Shape and Color	Size ( $\mu$ )	Activity at D + 30 (c/m)	Mass ( $\mu$ g) Density (g/cm <sup>3</sup> )
	Zuni	Whim Sample YFNB 29				
1			White Sphere		$1.51 \times 10^4$	
2			White Irregular		$3.05 \times 10^4$	2.4
3			White Irregular		$2.23 \times 10^4$	2.3
4			Yellow Sphere		$2.30 \times 10^5$	2.6
5			Yellow Sphere		$6.30 \times 10^5$	2.6
6			Yellow Sphere		$3.25 \times 10^5$	2.5
7			White Sphere		$1.40 \times 10^5$	2.6
8			Yellow Sphere		$9.6 \times 10^5$	2.3
9			Yellow Sphere		$3.7 \times 10^5$	2.2
10			Yellow Sphere		$7.9 \times 10^5$	2.5
11			Yellow Sphere		$7.0 \times 10^5$	2.3
12			Yellow Sphere		$1.1 \times 10^5$	2.6
13			Yellow Sphere		$2.05 \times 10^5$	2.6
14			White Sphere		$3.8 \times 10^4$	2.3

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SINGLE PARTICLE ANALYSIS

<u>Specification of Particle</u>			<u>Parameters</u>			
<u>No.</u>	<u>Event</u>	<u>Location</u>	<u>Shape and Color</u>	<u>Size (<math>\mu</math>)</u>	<u>Activity at D + 30 (c/m)</u>	<u>Mass (<math>\mu</math>g)</u> <u>Density (<math>\text{g/cm}^3</math>)</u>
	Zuni	Whim Sample YFNB 29				
15			Yellow Sphere		$3.5 \times 10^5$	2.3
16			1/2 White Sphere		$2.9 \times 10^5$	2.3
17			White Sphere		$1.09 \times 10^5$	2.0
18			White Sphere		$1.25 \times 10^5$	2.2
19			Yellow Sphere		$2.75 \times 10^4$	2.1
20			Yellow Sphere		$2.9 \times 10^5$	2.6
21			Yellow Irregular		$5.2 \times 10^3$	2.1
22			White Sphere		$3.3 \times 10^4$	2.1
23			Green Irregular		$3.7 \times 10^4$	2.3
24			Yellow Sphere		$4.9 \times 10^5$	2.7
25			White Sphere		$7.8 \times 10^4$	2.3
26			White Sphere		$4.0 \times 10^5$	2.7
27			Yellow Sphere		$2.08 \times 10^4$	2.3
28			Yellow Sphere		$4.6 \times 10^5$	2.0

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